

Multibody-System-Simulation of Drive Trains of Wind Turbines

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TECHNICAL PAPER

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[The statements and opinions contained herein are those of the author and should not be construed as an official action or opinion of the American Gear Manufacturers Association.]

Abstract

Dimensioning of wind turbines adequately to their expected operation loading – especially for Off-Shore-Applications with several MW output power – requires a very good knowledge of the dynamic loads of all possible operational situations. To reduce the need of risky and expensive measurements it is suggested to study the dynamic behavior of the wind turbine drive train by using the Multibody-System-Simulation. The actual possibilities of this method are demonstrated in the first part of this paper for a built wind turbine of 600 kW power output. The second part deals with the modeling of a single-stage planetary gear box in a 750-kW-Turbine taking also into account the parameter excitation of the tooth contact. This gear box model covers all relevant aspects to analyze drive trains of wind turbines up to 3 MW power output. The model expansion to a two-stage planetary gear box allows the dynamic analysis of wind turbines with an output higher than 4 MW. Further research work in the near future will concentrate on the connection between the wind simulation models for the rotor and drive train on the one hand and the coupling with the generator and the electrical network on the other hand with special regard to the control concepts.

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Introduction and Task

During the last years the share of wind power in relation to the total energy production in Germany has increased continuously with an annual growth of 35 %. The main reasons are the Eco-friendliness and a steady improvement of the used technology in connection with a continuous increase of the power output of the single wind turbine. 10 years ago the power output per unit was less than 300 kW, today's standard turbines have a power output of 1.5 MW. Some manufacturers have put into operation turbines of 2.5 MW and the whole wind industry branch works on the development of turbines with 5 to 6 MW power output which will only be suitable for „Off-Shore“-applications due to their large size. Because of the large power output increase the turbines have reached dimensions where operational influences have to be taken into account that are not comparable to stationary industrial plants. That means in detail high load peaks, load alternation influences in the drive train, high light load periods and aeroelastic vibrations at the rotor blades. In every case especially the drive train has to withstand very high dynamic loads because it connects directly the rotor (transforming the wind energy in rotational energy) with the generator (transforming the rotational energy into electrical energy). That means that both the dynamics of the wind loads and the dynamics of the electrical network act on the drive train. Very often deformations of the tower and the nacelle structure occur leading to additional loads on the drive train [1, 2].

A prerequisite for dimensioning a drive adequately for the expected strain is to know the kind of strain action as a function of time.

According to the "Richtlinie für die Zertifizierung von Windkraftanlagen" of the Germanischer Lloyd (GL) the representative cumulative frequency distribution of the location has to be taken into account [3]. It can be determined by measurement or calculation. It is easiest to measure the behavior under operational strain in the case of a built machine. In the past, measurements to this effect were quite frequently made on wind turbines [4, 5]. The high quality of these measurements does, however, require an enormous technical expenditure - apart from the fact that the object to be measured must be available.

In the case of a projected installation or a new or further development, this kind of measuring technique for determining strain is not possible, as there is no object available for measurements during the starting phase. According to the GL-Guideline [3] the wind turbine could be dimensioned with a simplified single-stage cumulative frequency distribution and taking into account dynamic loads by the application factor k_A analogous to DIN 3990 [6]. In general the application factor amounts to $k_A = 1,5$, for rotors with three blades it is allowed to use $k_A = 1,3$ [3]. Investigations of drive trains in other applications but with comparable power output have shown in the past, that the lump sum consideration of dynamic loads by an application factor leads very often to unsatisfactory results [5, 7, 8]. There is the general danger of wrong dimensioning. In the case of a wind turbine the over dimensioning is not desirable because of the light weight design requirements. On the other hand a dimensioning of too low capacity causes failures of the drive train with production losses and high repair and maintenance costs. To avoid this problems

one can either resort to analogy in order to obtain suitable load assumptions, or derive conclusions from comparable kinematic chains to determine the strains to be expected, or use a suitable simulation procedure in order to accurately predict the operational strain that may occur. Furthermore simulation has the advantage that special load cases can also be considered, cases which do not occur in normal operation, but are important for dimensioning, as they could, under certain circumstances, destroy the drive train or the entire turbine [9, 10, 11, 12, 13]. Especially the last aspect will be of more significance for the dimensioning of wind turbines for Off-Shore-Applications. Therefore the following example of a wind turbine with 600 kW output rate (Fig. 1) should demonstrate the actual possibilities of the Multibody-System-Simulation to determine the dynamic behavior of drive trains.

Creating a simulation model of the drive train

Technical installations are oscillatory continua with infinitely many degrees of freedom. A

detailed investigation of a limited number of degrees of freedom is, as a rule, entirely sufficient for analyzing dynamic behavior. Consequently, it is sensible to look at a mathematical model that reflects the relevant features of the real technical system as accurately as possible. Basically, we differentiate between models with distributed parameters - for example, elastic bodies in continuum mechanics - and models with concentrated parameters [14].

For models with concentrated parameters, characteristics such as inertia, elasticity, viscosity and force of the real system are attributed to individual discrete elements. With the help of these discrete elements which comprise the rigid body, the massless spring and the massless damper, as well as drive and reaction forces or moments, it is possible to build general three-dimensional multi-body-systems. Any restrictions on movement (linkages) between the bodies are realized with joints with specific properties. Such mechanical systems are described mathematically by ordinary coupled differential equations and algebraic equations.



Fig. 1: Investigated Wind Turbine NEG-Micon Type NTK 600/43